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PATENT COOPERATION TREATY

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INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

(Chapter II of the Patent Cooperation Treaty)

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference AWP/P58023WO00	FOR FURTHER ACTION See Form PCT/IPEA/416	
International application No. PCT/GB2004/002268	International filing date *(day/month/year)* 28.05.2004	Priority date *(day/month/year)* 28.05.2003
International Patent Classification (IPC) or national classification and IPC F02B75/00, F01B17/02, F02D17/02		
Applicant LOTUS CARS LIMITED et al.		

1. This report is the international preliminary examination report, established by this International Preliminary Examining Authority under Article 35 and transmitted to the applicant according to Article 36.
2. This REPORT consists of a total of 8 sheets, including this cover sheet.
3. This report is also accompanied by ANNEXES, comprising:
   a. ☒ *sent to the applicant and to the International Bureau)* a total of 24 sheets, as follows:
      ☒ sheets of the description, claims and/or drawings which have been amended and are the basis of this report and/or sheets containing rectifications authorized by this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions).
      ☐ sheets which supersede earlier sheets, but which this Authority considers contain an amendment that goes beyond the disclosure in the international application as filed, as indicated in item 4 of Box No. I and the Supplemental Box.
   b. ☐ *(sent to the International Bureau only)* a total of (indicate type and number of electronic carrier(s)) , containing a sequence listing and/or tables related thereto, in computer readable form only, as indicated in the Supplemental Box Relating to Sequence Listing (see Section 802 of the Administrative Instructions).

4. This report contains indications relating to the following items:

☒	Box No. I	Basis of the opinion
☐	Box No. II	Priority
☐	Box No. III	Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
☐	Box No. IV	Lack of unity of invention
☒	Box No. V	Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
☐	Box No. VI	Certain documents cited
☒	Box No. VII	Certain defects in the international application
☒	Box No. VIII	Certain observations on the international application

Date of submission of the demand	Date of completion of this report
29.03.2005	14.09.2005
Name and mailing address of the international preliminary examining authority: European Patent Office - P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk - Pays Bas Tel. +31 70 340 - 2040 Tx: 31 651 epo nl Fax: +31 70 340 - 3016	Authorized Officer Paquay, J Telephone No. +31 70 340-3944

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

International application No.
PCT/GB2004/002268

Box No. I Basis of the report

1. With regard to the **language**, this report is based on the international application in the language in which it was filed, unless otherwise indicated under this item.

   ☐ This report is based on translations from the original language into the following language , which is the language of a translation furnished for the purposes of:
   - ☐ international search (under Rules 12.3 and 23.1(b))
   - ☐ publication of the international application (under Rule 12.4)
   - ☐ international preliminary examination (under Rules 55.2 and/or 55.3)

2. With regard to the **elements*** of the international application, this report is based on *(replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report)*:

Description, Pages	
1-19	as originally filed
Claims, Numbers	
1-42	received on 29.03.2005 with letter of 29.03.2005
Drawings, Sheets	
1/3-3/3	as originally filed

   ☐ a sequence listing and/or any related table(s) - see Supplemental Box Relating to Sequence Listing

3. ☐ The amendments have resulted in the cancellation of:
   - ☐ the description, pages
   - ☐ the claims, Nos.
   - ☐ the drawings, sheets/figs
   - ☐ the sequence listing *(specify)*:
   - ☐ any table(s) related to sequence listing *(specify)*:

4. ☐ This report has been established as if (some of) the amendments annexed to this report and listed below had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).
   - ☐ the description, pages
   - ☐ the claims, Nos.
   - ☐ the drawings, sheets/figs
   - ☐ the sequence listing *(specify)*:
   - ☐ any table(s) related to sequence listing *(specify)*:

* *If item 4 applies, some or all of these sheets may be marked "superseded."*

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

International application No.
PCT/GB2004/002268

Box No. V Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-43
	No:	Claims	
Inventive step (IS)	Yes:	Claims	1-43
	No:	Claims	
Industrial applicability (IA)	Yes:	Claims	1-43
	No:	Claims	

2. Citations and explanations (Rule 70.7):

see separate sheet

Box No. VII Certain defects in the international application

The following defects in the form or contents of the international application have been noted:

see separate sheet

Box No. VIII Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

see separate sheet

Re Item V

Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

Reference is made to the following document:
D1: US 2001/002379 A1 (SCHECHTER MICHAEL M) 31 May 2001 (2001-05-31)
This document D1 is regarded as being the closest prior art to the subject-matter of all the independent claims.

1 To independent claim 1: Document D1 does not show the features of the lines 15 to 27 of page 21. Because of this difference, the subject-matter of the first claim is new in the sense of Article 33(2) PCT.

The new claim 1 claims (among others) an engine with a variable volume chamber and 5 different operating modes for this engine. Some of these operating modes are known on its own, but the implementation of all these modes together in one engine requires, especially with the complex lay out of the engine (a variable volume chamber engine, combined with a reservoir for storing compressed air) a lot of development, tuning and testing. In view of this, the subject-matter of the first claim is also inventive (Article 33(3)PCT).

2 To independent claim 2: Document D1 does not show the features of the lines 12 to 24 of page 23. Because of this difference, the subject-matter of claim 2 is new in the sense of Article 33(2) PCT.

The new claim 2 claims (among others) an engine with a variable volume chamber and 5 different operating modes for this engine. Some of these operating modes are known on its own, but the implementation of all these modes together in one engine requires, especially with the complex lay out of the engine (a variable volume chamber engine, combined with a reservoir for storing compressed air) requires a lot of development, tuning and testing. In view of this, the subject-matter of claim 2 is also inventive (Article 33(3)PCT).

3 To independent claim 7: Document D1 does not show the features of the lines 28 to 30 of page 25 and the lines 1-14 of page 26. Because of this difference, the subject-matter of claim 7 is new in the sense of Article 33(2) PCT.

The new claim 7 claims (among others) an engine with a variable volume chamber and 3 different operating modes for this engine. One of these operating modes distinguishes between a two- and a four-stroke mode. The implementation of all these modes together in one engine, especially with the complex lay out of the engine (a variable volume chamber engine, combined with a reservoir for storing compressed air) requires a lot of development, tuning and testing. In view of this, the subject-matter of claim 7 is also inventive (Article 33(3)PCT).

4 To independent claim 12: Document D1 does not show the features of the lines 19 to 23 of page 28. Because of this difference, the subject-matter of claim 12 is new in the sense of Article 33(2) PCT.

The new claim 12 claims (among others) an engine with a variable volume chamber, a pump and 3 different operating modes for this engine. The implementation of all these modes together in one engine, especially with the complex lay out of the engine (a variable volume chamber engine, combined with a pump and reservoir for storing compressed air) requires a lot of development, tuning and testing. In view of this, the subject-matter of claim 12 is also inventive (Article 33(3)PCT).

5 To independent claim 15: Document D1 does not show the features of the lines 19 to 22 of page 30. Because of this difference, the subject-matter of claim 15 is new in the sense of Article 33(2) PCT.

The new claim 15 claims (among others) an engine with a variable volume chamber, an electrical driven turbocharger and 3 different operating modes for this engine. The implementation of all these modes together in one engine, especially with the complex lay out of the engine (a variable volume chamber engine, combined with an electrical driven turbocharger) requires a lot of development, tuning and testing. In view of this, the subject-matter of claim 15 is also inventive (Article 33(3)PCT).

6 To independent claim 24: Document D1 does not show the features of the lines 16 to 21 of page 34. Because of this difference, the subject-matter of claim 24 is new in the sense of Article 33(2) PCT.

The new claim 24 claims (among others) an engine with a plurality of variable volume chambers, 3 different operating modes for this engine and the operating of different variable volume chambers according to a different mode at the same time. The implementation of all these modes together in one engine, especially with the complex lay out of the engine (a variable volume chamber engine, combined with a reservoir for storing compressed air) requires a lot of development, tuning and testing. In view of this, the subject-matter of claim 24 is also inventive (Article 33(3)PCT).

7 To independent claim 33: Document D1 does not show the features of the lines 24 to 31 of page 38 and the features of the lines 1 to 16 of page 39. Because of this difference, the subject-matter of claim 33 is new in the sense of Article 33(2) PCT.

The new claim 33 claims (among others) an engine with a plurality of variable volume chambers, 3 different operating modes and the deactivation of at least one of the variable volume chambers. The implementation of all this together in one engine, especially with the complex lay out of the engine (a variable volume chamber engine, the reservoir for storing compressed air and all the sensors) requires a lot of development, tuning and testing. In view of this, the subject-matter of claim 33 is also inventive (Article 33(3)PCT).

8 To independent claim 35: Document D1 does not show the features of the lines 20 to 26 of page 41. Because of this difference, the subject-matter of claim 35 is new in the sense of Article 33(2) PCT.

The new claim 35 claims (among others) an engine with a plurality of variable volume chambers, 3 different operating modes and the interconnection of the plurality of variable volume chambers with the goal of expanding the air. The implementation of all this together in one engine, especially with the complex lay out of the engine (a

variable volume chamber engine, the reservoir for storing compressed air and the interconnection of the variable volume chambers) requires a lot of development, tuning and testing. In view of this, the subject-matter of claim 35 is also inventive (Article 33(3)PCT).

Re Item VII
Certain defects in the international application

1 The features of the claims 1-42 are not provided with reference signs placed in parentheses (Rule 6.2(b) PCT).

2 Contrary to the requirements of Rule 5.1(a)(ii) PCT, the relevant background art disclosed in the document D1 is not mentioned in the description, nor is this document identified therein.

Re Item VIII
Certain observations on the international application

The application does not meet the requirements of Article 6 PCT, because claims 1, 7, 12, 13, 24, 33 and 35 are not clear.

1 The claims 1, 7, 12, 24, 33 and 35 have been drafted as separate independent claims. Nevertheless, the claims 7, 12, 24, 33 and 35 seem to appear to relate effectively to the same subject-matter as claim 1. The aforementioned claims therefore lack conciseness and as such do not meet the requirements of Article 6 PCT.

2 To claim 13: This claim claims a pressure reach from "100 to 100" bar, This one value for an entire reach leaves the reader in doubt as to the meant pressure reach, thereby rendering the definition of the subject-matter of said claims unclear, Article 6

PCT.

CLAIMS

1. An engine comprising:

a variable volume chamber;

inlet valve means controlling admission of charge air into the variable volume chamber;

fuel delivery means for delivering fuel to be mixed with the charge air admitted to the variable volume chamber; and

exhaust valve means for controlling exhaust to atmosphere from the variable volume chamber of combusted gases resulting from combustion in the variable volume chamber of the fuel with the admitted charge air;

wherein:

the engine has a first operating mode in which the inlet valve means admits charge air into the variable volume chamber, the fuel delivery means delivers fuel which is mixed with the admitted charge air, the mixture of fuel and charge air is compressed by the variable volume chamber reducing in volume, the compressed mixture of fuel and air combusts, the combusted gases expand and force the variable volume chamber to increase in volume and the expanded combusted gases are exhausted to atmosphere from the variable volume chamber via the exhaust valve means;

wherein the engine additionally comprises:

a reservoir for storing compressed air which is connected to the variable volume chamber; and

gas flow control valve means controlling flow of air between the variable volume chamber and the reservoir for storing compressed air;

and wherein the engine has at least the following operating modes:

a second operating mode in which the inlet valve means admits charge air into the variable volume chamber, the admitted charge air is compressed by the variable volume chamber reducing in volume and the gas flow control valve means allows the compressed air to flow from the variable volume chamber to the reservoir to be stored therein; and

a third operating mode in which the gas flow control valve means allows compressed air to flow from the reservoir into the variable volume chamber and thereafter expand to force the variable volume chamber to increase in volume, the expanded air subsequently being exhausted to atmosphere; and has a fourth operating mode in which the inlet valve means admits charge air into the variable volume chamber, the admitted charge air is compressed by the variable volume chamber reducing in volume and the exhaust valve means allows the compressed air to be exhausted to atmosphere; and

the engine being characterised by a fifth operating mode in which: air or combusted gases is/are trapped in the variable volume chamber by closing all of the inlet valve means, the exhaust valve means and the gas flow control valve means, and in which the variable volume chamber with the trapped air or combusted gases operate(s) as a gas spring.

2. An engine comprising:

a variable volume chamber;

inlet valve means controlling admission of charge air into the variable volume chamber;

fuel delivery means for delivering fuel to be mixed with the charge air admitted to the variable volume chamber; and

exhaust valve means for controlling exhaust to atmosphere from the variable volume chamber of combusted gases resulting from combustion in the variable volume chamber of the fuel with the admitted charge air;

wherein:

the engine has a first operating mode in which the inlet valve means admits charge air into the variable volume chamber, the fuel delivery means delivers fuel which is mixed with the admitted charge air, the mixture of fuel and charge air is compressed by the variable volume chamber reducing in volume, the compressed mixture of fuel and air combusts, the combusted gases expand and force the variable volume chamber to increase in volume and the expanded combusted gases are exhausted to atmosphere from the variable volume chamber via the exhaust valve means;

wherein the engine additionally comprises:

a reservoir for storing compressed air which is connected to the variable volume chamber; and

gas flow control valve means controlling flow of air between the variable volume chamber and the reservoir for storing compressed air;

and wherein the engine has at least the following operating modes:

a second operating mode in which the inlet valve means admits charge air into the variable volume chamber,

the admitted charge air is compressed by the variable volume chamber reducing in volume and the gas flow control valve means allows the compressed air to flow from the variable volume chamber to the reservoir to be stored therein;

a third operating mode in which the gas flow control valve means allows compressed air to flow from the reservoir into the variable volume chamber and thereafter expand to force the variable volume chamber to increase in volume, the expanded air subsequently being exhausted to atmosphere;

a fourth operating mode in which the inlet valve means admits charge air into the variable volume chamber, the admitted charge air is compressed by the variable volume chamber reducing in volume and the inlet valve means allows the compressed air to be exhausted to atmosphere; and

the engine is characterised by a fifth operating mode in which: air or combusted gases is/are trapped in the variable volume chamber by closing all of the inlet valve means, the exhaust valve means and the gas flow control valve means, and in which the variable volume chamber with the trapped air or combusted gases operate(s) as a gas spring.

3. An engine as claimed in claim 1 or claim 2 wherein the expanded air is exhausted to atmosphere via the exhaust valve means.

4. An engine as claimed in claim 1 or claim 2 wherein the expanded air is exhausted to atmosphere via the inlet valve means.

5. An engine as claimed in any one of the preceding claims, wherein the fuel delivery means is deactivated whilst the engine is operating in the fifth operating mode.

6. An engine as claimed in any one of the preceding claims wherein the fuel delivery means is deactivated whilst the engine is operating in the fourth operating mode.

7. An engine comprising:

a variable volume chamber;

inlet valve means controlling admission of charge air into the variable volume chamber;

fuel delivery means for delivering fuel to be mixed with the charge air admitted to the variable volume chamber; and

exhaust valve means for controlling exhaust to atmosphere from the variable volume chamber of combusted gases resulting from combustion in the variable volume chamber of the fuel with the admitted charge air;

wherein:

the engine has a first operating mode in which the inlet valve means admits charge air into the variable volume chamber, the fuel delivery means delivers fuel which is mixed with the admitted charge air, the mixture of fuel and charge air is compressed by the variable

volume chamber reducing in volume, the compressed mixture of fuel and air combusts, the combusted gases expand and force the variable volume chamber to increase in volume and the expanded combusted gases are exhausted to atmosphere from the variable volume chamber via the exhaust valve means;

wherein the engine additionally comprises:

a reservoir for storing compressed air which is connected to the variable volume chamber; and

gas flow control valve means controlling flow of air between the variable volume chamber and the reservoir for storing compressed air;

and wherein the engine has at least the following operating modes:

a second operating mode in which the inlet valve means admits charge air into the variable volume chamber, the admitted charge air is compressed by the variable volume chamber reducing in volume and the gas flow control valve means allows the compressed air to flow from the variable volume chamber to the reservoir to be stored therein; and

a third operating mode in which the gas flow control valve means allows compressed air to flow from the reservoir into the variable volume chamber and thereafter expand to force the variable volume chamber to increase in volume, the expanded air subsequently being exhausted to atmosphere;

wherein when the engine is operating in the third operating mode then the engine can operate a two-stroke cycle with the gas flow control valve means admitting

compressed air into the variable volume chamber during each downstroke; and

wherein when the engine is operating in the third operating mode then the engine can operate a four-stroke cycle with an intake stroke in which the inlet valve means allows fresh charge air to be drawn into the variable volume chamber, a compression stroke in which the charge air admitted via the inlet valve means is compressed, a power stroke in which the gas flow control valve means admits compressed air into the variable volume chamber to supplement the air previously compressed in the compression stroke and an exhaust stroke in which expanded air is expelled from the variable volume chamber.

8. An engine as claimed in any one of the preceding claims wherein the fuel delivery means is deactivated whilst the engine is operating in the second operating mode.

9. An engine as claimed in any one of the preceding claims wherein the fuel delivery means is deactivated whilst the engine is operating in the third operating mode.

10. An engine as claimed in any one of the preceding claims wherein the air compressed in the variable volume chamber in the second operating mode of the engine is compressed to a pressure in the range 10 to 20 bar.

11. An engine as claimed in any one of the preceding claims wherein the reservoir comprises a light plastic pressure vessel.

12. An engine comprising:

a variable volume chamber;

inlet valve means controlling admission of charge air into the variable volume chamber;

fuel delivery means for delivering fuel to be mixed with the charge air admitted to the variable volume chamber; and

exhaust valve means for controlling exhaust to atmosphere from the variable volume chamber of combusted gases resulting from combustion in the variable volume chamber of the fuel with the admitted charge air; wherein:

the engine has a first operating mode in which the inlet valve means admits charge air into the variable volume chamber, the fuel delivery means delivers fuel which is mixed with the admitted charge air, the mixture of fuel and charge air is compressed by the variable volume chamber reducing in volume, the compressed mixture of fuel and air combusts, the combusted gases expand and force the variable volume chamber to increase in volume and the expanded combusted gases are exhausted to atmosphere from the variable volume chamber via the exhaust valve means;

wherein the engine additionally comprises:

a reservoir for storing compressed air which is connected to the variable volume chamber; and

gas flow control valve means controlling flow of air between the variable volume chamber and the reservoir for storing compressed air;

and wherein the engine has at least two additional operating modes:

a second operating mode in which the inlet valve means admits charge air into the variable volume chamber, the admitted charge air is compressed by the variable volume chamber reducing in volume and the gas flow control valve means allows the compressed air to flow from the variable volume chamber to the reservoir to be stored therein; and

a third operating mode in which the gas flow control valve means allows compressed air to flow from the reservoir into the variable volume chamber and thereafter expand to force the variable volume chamber to increase in volume, the expanded air subsequently being exhausted to atmosphere; and

characterised in that the engine comprises additionally a pump powered by the engine which receives compressed air expelled from the variable volume chamber and compresses the air further before the compressed air is delivered to the reservoir.

13. An engine as claimed in claim 12 wherein the pump raises the pressure of the compressed air from an initial pressure in the range 10 to 20 bar to a higher pressure of 100 to 100 bar.

14. An engine as claimed in any one of claims 1 to 11 comprising additionally an engine-driven supercharger

which pressurises the charge air admitted into the variable volume chamber via the inlet valve means.

15. An engine comprising:

a variable volume chamber;

inlet valve means controlling admission of charge air into the variable volume chamber;

fuel delivery means for delivering fuel to be mixed with the charge air admitted to the variable volume chamber; and

exhaust valve means for controlling exhaust to atmosphere from the variable volume chamber of combusted gases resulting from combustion in the variable volume chamber of the fuel with the admitted charge air;

wherein:

the engine has a first operating mode in which the inlet valve means admits charge air into the variable volume chamber, the fuel delivery means delivers fuel which is mixed with the admitted charge air, the mixture of fuel and charge air is compressed by the variable volume chamber reducing in volume, the compressed mixture of fuel and air combusts, the combusted gases expand and force the variable volume chamber to increase in volume and the expanded combusted gases are exhausted to atmosphere from the variable volume chamber via the exhaust valve means;

wherein the engine additionally comprises:

a reservoir for storing compressed air which is connected to the variable volume chamber; and

gas flow control valve means controlling flow of air between the variable volume chamber and the reservoir for storing compressed air;

and wherein the engine has at least two additional operating modes:

a second operating mode in which the inlet valve means admits charge air into the variable volume chamber, the admitted charge air is compressed by the variable volume chamber reducing in volume and the gas flow control valve means allows the compressed air to flow from the variable volume chamber to the reservoir to be stored therein; and

a third operating mode in which the gas flow control valve means allows compressed air to flow from the reservoir into the variable volume chamber and thereafter expand to force the variable volume chamber to increase in volume, the expanded air subsequently being exhausted to atmosphere; and

characterised in that the engine comprises additionally an electrically-driven turbocharger which pressurises the charge air admitted into the variable volume chamber via the inlet valve means.

16. An engine as claimed in claims 12 to 15 wherein the reservoir comprises a steel pressure vessel.

17. An engine as claimed in any one of the preceding claims, wherein the variable volume chamber is defined between a piston and a surrounding cylinder, the piston reciprocating in the cylinder and the piston being connected to a crankshaft of the engine.

18. An engine as claimed in any one of the preceding claims wherein each of the inlet valve means, the exhaust valve means and the gas flow control valve means comprises a valve operated by a hydraulic actuator individual to the valve and all of the hydraulic actuators are controlled by a common electronic controller, the electronic controller receiving signals from a plurality of sensors and the electronic controller varying operation of the hydraulic actuators and thereby operation of the valves in order to switch operation of the engine between the operating modes thereof.

19. A vehicle comprising an engine as claimed in claim 18 wherein the plurality of sensors includes sensors measuring parameters relating to motion of the vehicle and a sensor measuring pressure of air stored in the reservoir and wherein the electronic controller on detecting that the vehicle is decelerating whilst the reservoir is depleted varies operation of the hydraulic actuators so that the engine operates in the second operating mode.

20. A vehicle as claimed in claim 19 which has an automatic transmission with a variable gear ratio and wherein the electronic controller controls the transmission to lower the gear ratio when the vehicle is decelerating in order to increase revolutionary speed of the engine.

21. A vehicle comprising an engine as claimed in claim 19 or 20 wherein the plurality of sensors includes sensors measuring parameters relating to motion of the vehicle and a sensor measuring pressure of air stored in the reservoir and the electronic controller on detecting that the valve is decelerating whilst the reservoir is full varies operation of the hydraulic actuators so that the engine operates in the fourth operating mode.

22. A vehicle comprising an engine as claimed in claim 19 wherein the plurality of sensors includes sensors measuring parameters relating to motion of the vehicle and to requirements of a driver and the electronic controller on detecting that the vehicle is stationary and the driver wishes the vehicle to start moving controls operation of the hydraulic actuators so that the engine operates initially in the third operating mode and then, as speed of the vehicle increases, the operation of the hydraulic actuators is varied so that the engine switches to the first operating mode.

23. A vehicle as claimed in claim 22 wherein the vehicle commences motion without use of a clutch.

24. An engine comprising:

a plurality of variable volume chambers;

inlet valve means controlling admission of charge air into the variable volume chambers;

fuel delivery means for delivering fuel to be mixed with the charge air admitted to the variable volume chambers; and

exhaust valve means for controlling exhaust to atmosphere from the variable volume chambers of combusted gases resulting from combustion in the variable volume chambers of the fuel with the admitted charge air;

wherein

the engine can operate at least one of the plurality of variable volume chambers in a plurality of different operating modes; and

the engine can operate each variable volume chamber in a first operating mode in which the inlet valve means admits charge air into the variable volume chamber, the fuel delivery means delivers fuel which is mixed with the admitted charge air, the mixture of fuel and charge air is compressed by the variable volume chamber reducing in volume, the compressed mixture of fuel and air combusts, the combusted gases expand and force the variable volume chamber to increase in volume and the expanded combusted gases are exhausted to atmosphere from the variable volume chamber via the exhaust valve means;

wherein:

the engine additionally comprises:

a reservoir for storing compressed air which is connected to at least one of the plurality of variable volume chambers; and

gas flow control valve means controlling flow of gas between at least one of the variable volume chambers and the reservoir for storing compressed air;

and wherein the engine can operate at least one of the plurality of variable volume chambers in at least two additional operating modes:

a second operating mode in which the inlet valve means admits charge air into the variable volume chamber, the admitted charge air is compressed by the variable volume chamber reducing in volume and the gas flow control valve means allows the compressed air to flow from the variable volume chamber to the reservoir to be stored therein;

a third operating mode in which the gas flow control valve means allows compressed air to flow from the reservoir into the variable volume chamber and thereafter expand to force the variable volume chamber to increase in volume, the expanded air subsequently being exhausted to atmosphere; and

characterised in that the engine can simultaneously operate a first of the variable volume chambers according to the first operating mode while operating a second of the variable volume chambers according to the second operating mode whereby some of the work derived from the expansion of the combusted gases in the first variable volume chamber is used to compress air in the second variable volume chamber.

25. An engine as claimed in claim 24 wherein in the third operating mode the expanded air is exhausted to atmosphere via the exhaust valve means.

26. An engine as claimed in claim 24 wherein in the third operating mode the expanded air is exhausted to atmosphere via the inlet valve means.

27. An engine as claimed in any one of claims 24 to 26 wherein each variable volume chamber is defined between a stationary element and a movable element and all of the movable elements are connected to a common power output mechanism whereby work derived from expansion of combusted gases can be output from the engine and also transferred between the movable elements.

28. An engine as claimed in claim 27 wherein the stationary elements are cylinders in a cylinder block and the movable elements are pistons which reciprocate one in each of the cylinders and the power output mechanism comprises a crankshaft to which all of the pistons are connected.

29. An engine as claimed in any of claims 24 to 28 wherein each of the inlet valve means, the exhaust valve means and the gas flow control valve means comprises a valve operated by a hydraulic actuator individual to the valve and all of the hydraulic actuators are controlled by a common electronic controller, the electronic controller receiving signals from a plurality of sensors and varying operation of the hydraulic actuators and thereby the valves in order to control the mode of operation of each variable volume chamber of the engine.

30. An engine as claimed in claim 29 wherein the plurality of sensors includes sensors measuring parameters relating to load on the engine and a sensor measuring pressure of air stored in the reservoir and the electronic controller on detecting that the engine is

part loaded and that the reservoir is depleted controls operation of the hydraulic actuators so that at least a first variable volume chamber is operating in the first operating mode and delivering power output from the engine and at least a second variable volume chamber is operating in the second operating mode and compressing air for delivery to the reservoir.

31. An engine as claimed in claim 29 wherein the plurality of sensors includes sensors measuring parameters relating to load on the engine and a sensor measuring pressure of air stored in the reservoir and the electronic controller on detecting that the engine is part loaded and that the reservoir is full controls operation of the hydraulic actuators so that first variable volume chamber is operating in the first operating mode and delivering power output from the engine and at least a second variable volume chamber is deactivated by closing the inlet valve means, the exhaust valve means and the gas flow control valve means specific thereto with air or combusted gases trapped in the second variable volume chamber which thereby functions as a gas spring.

32. An engine as claimed in any one of claims 24 to 26 wherein the plurality of variable volume chambers are interconnected by conduit means and when the engine is operating in the second operating mode then the admitted charge air admitted into the said variable valve chamber and compressed therein when allowed to flow from the chamber by the gas flow control volume means flows to at

least a second variable valve chamber in which the air is compressed further before flowing to the variable volume chamber to be stored therein.

33. An engine comprising:

a plurality of variable volume chambers;

inlet valve means controlling admission of charge air into the variable volume chambers;

fuel delivery means for delivering fuel to be mixed with the charge air admitted to the variable volume chambers; and

exhaust valve means for controlling exhaust to atmosphere from the variable volume chambers of combusted gases resulting from combustion in the variable volume chambers of the fuel with the admitted charge air; wherein

the engine can operate at least one of the plurality of variable volume chambers in a plurality of different operating modes; and

the engine can operate each variable volume chamber in a first operating mode in which the inlet valve means admits charge air into the variable volume chamber, the fuel delivery means delivers fuel which is mixed with the admitted charge air, the mixture of fuel and charge air is compressed by the variable volume chamber reducing in volume, the compressed mixture of fuel and air combusts, the combusted gases expand and force the variable volume chamber to increase in volume and the expanded combusted gases are exhausted to atmosphere from the variable volume chamber via the exhaust valve means;

wherein:

the engine additionally comprises:

a reservoir for storing compressed air which is connected to at least one of the plurality of variable volume chambers; and

gas flow control valve means controlling flow of gas between at least one of the variable volume chambers and the reservoir for storing compressed air;

and wherein the engine can operate at least one of the plurality of variable volume chambers in at least two additional operating modes:

a second operating mode in which the inlet valve means admits charge air into the variable volume chamber, the admitted charge air is compressed by the variable volume chamber reducing in volume and the gas flow control valve means allows the compressed air to flow from the variable volume chamber to the reservoir to be stored therein; and

a third operating mode in which the gas flow control valve means allows compressed air to flow from the reservoir into the variable volume chamber and thereafter expand to force the variable volume chamber to increase in volume, the expanded air subsequently being exhausted to atmosphere; and

wherein each of the inlet valve means, the exhaust valve means and the gas flow control valve means comprises a valve operated by a hydraulic actuator individual to the valve and all of the hydraulic actuators are controlled by a common electronic controller, the electronic controller receiving signals from a plurality of sensors and varying operation of the hydraulic actuators and thereby the valves in order to

control the mode of operation of each variable volume chamber of the engine; and

characterised in that the plurality of sensors includes sensors measuring parameters relating to load on the engine and a sensor measuring pressure of air stored in the reservoir and the electronic controller on detecting that the engine is part loaded and that the reservoir is full controls operation of the hydraulic actuators so that first variable volume chamber is operating in the first operating mode and delivering power output from the engine and at least a second variable volume chamber is deactivated by closing the inlet valve means, the exhaust valve means and the gas flow control valve means specific thereto with air or combusted gases trapped in the second variable volume chamber which thereby functions as a gas spring.

34. An engine as claimed in claim 33 wherein the plurality of variable volume chambers are interconnected by conduit means and when the engine is operating in the second operating mode then the admitted charge air admitted into the said variable valve chamber and compressed therein when allowed to flow from the chamber by the gas flow control volume means flows to at least a second variable valve chamber in which the air is compressed further before flowing to the variable volume chamber to be stored therein.

35. An engine comprising:

a plurality of variable volume chambers;

inlet valve means controlling admission of charge air into the variable volume chambers;

fuel delivery means for delivering fuel to be mixed with the charge air admitted to the variable volume chambers; and

exhaust valve means for controlling exhaust to atmosphere from the variable volume chambers of combusted gases resulting from combustion in the variable volume chambers of the fuel with the admitted charge air;

wherein

the engine can operate at least one of the plurality of variable volume chambers in a plurality of different operating modes; and

the engine can operate each variable volume chamber in a first operating mode in which the inlet valve means admits charge air into the variable volume chamber, the fuel delivery means delivers fuel which is mixed with the admitted charge air, the mixture of fuel and charge air is compressed by the variable volume chamber reducing in volume, the compressed mixture of fuel and air combusts, the combusted gases expand and force the variable volume chamber to increase in volume and the expanded combusted gases are exhausted to atmosphere from the variable volume chamber via the exhaust valve means;

wherein:

the engine additionally comprises:

a reservoir for storing compressed air which is connected to at least one of the plurality of variable volume chambers; and

gas flow control valve means controlling flow of gas between at least one of the variable volume chambers and the reservoir for storing compressed air;

and wherein the engine can operate at least one of the plurality of variable volume chambers in at least two additional operating modes:

a second operating mode in which the inlet valve means admits charge air into the variable volume chamber, the admitted charge air is compressed by the variable volume chamber reducing in volume and the gas flow control valve means allows the compressed air to flow from the variable volume chamber to the reservoir to be stored therein; and

a third operating mode in which the gas flow control valve means allows compressed air to flow from the reservoir into the variable volume chamber and thereafter expand to force the variable volume chamber to increase in volume, the expanded air subsequently being exhausted to atmosphere; characterised in that:

the plurality of variable volume chambers are interconnected by conduit means and when the engine is operating in the third operating mode then the air expanded in said variable volume chamber is exhausted via the exhaust means to at least a second variable volume chamber for further expansion therein before the air is exhausted to atmosphere.

36. A valve mechanism for controlling flow of pressurised gas into an engine cylinder of an internal combustion engine, the mechanism comprising:

a poppet valve for opening and closing a transfer port in the cylinder through which gas can flow between a source of pressurised gas and the cylinder, the poppet valve having a valve head and a valve stem;

drive means acting on the valve stem for driving the poppet valve to open the transport port; and

spring means for biassing the poppet valve to close the transfer port; characterised in that:

on the valve stem there is mounted a piston which is slidable in a valve stem chamber provided in the internal combustion engine; and

the valve stem chamber is connected to the source of pressurised gas; whereby:

a force is applied to the piston by the pressurised gas in the valve stem chamber which counteracts a force applied on the poppet valve by exposure of a rear face of the valve head, facing away from the engine cylinder, to the pressurised gas from the source of pressurised gas.

37. A valve mechanism as claimed in claim 36 wherein sealing means is provided between the piston and the valve stem chamber to prevent escape of pressurised gas past the piston.

38. A valve mechanism as claimed in claim 36 or claim 37 comprising an isolating control valve operable to selectively connect and disconnect the valve stem chamber and the source of pressurised gas.

39. A valve mechanism as claimed in any one of claims 36 to 38 wherein the spring means comprises a spring located

in the valve stem chamber acting on the valve stem mounted piston.

40. A valve mechanism as claimed in any one of claims 36 to 39 wherein the internal combustion engine has a transfer passage leading from the source of pressurised gas to the engine cylinder and opening into the engine cylinder via the transfer port; and the valve stem cylinder is connected to the transfer passage.

41. A valve mechanism as claimed in any one of claims 36 to 40 wherein the drive means comprises a hydraulic actuator controlled by an electronic controller.

42. An internal combustion engine as claimed in any one of claims 1 to 35 wherein the gas flow control valve means comprises a valve mechanism as claimed in any one of claims 36 to 41.